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ORDERED OR RANDOM MIXING : CHOICE OF SYSTEM AND MIXER

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When confronted with a powder mixing operation, the properties of the materials have to be initally considered. If they are free flowing, they will be subjected to random mixing and to segregation. A suitable mixer will be chosen largely on the basis of avoiding dead-spots, rapid randomisation and avoiding segregation.

If the materials, (or one of them) are cohesive, then they will be mixed by an ordered mechanism and will not be subject to segregation. Even if the constituents are free-flowing, it may be desirous to make them cohesive by reducing particle size or addition of a suitable adhesive agent.

The choice of mixer for an ordered mixing operation requires avoidance of dead-spots, and break down of cohering agglomerates, whilst building up ordered mix units. Mixers suitable range from tumbling mixers through to high speed mixer granulators. The classification of mixers according to their possible ability to produce an ordered mixture is the subject of this paper.

INTRODUCTION

The randomisation process has, for many years, been considered as the only method of powder mixing. The theory requires that the particles are free-flowing and or equal size and density. Interaction between particles is not allowed and the shape and surface properties of the particles should not affect their ability to mix in a random fashion, in a truly statistical sense (Ref.1 and 2).

Ordered mixing requires an interaction between particles such that adherence or coating occurs. The particles are not required to be of equal size, or equal density or shape. Surface forces in at least one of the powders should be such that a high degree of adhesion will occur (Ref. 3)

In powder mixing practice, it is improbable that the situation where random mixing could occur would ever be achieved. Much of the work on evaluation of mixers and of the powder mixing process towards homogeneity has, however, been based on the dubious premise that random mixing occurs. It is necessary to disregard much of the published work in this area for this reason.

The powder technologist confronted with a powder mixing problem has two choices:

(i) - the choice of which mixer to use

(ii) - the choice of an ordered mixing or a random mixing approach to the problem.

These two electives are not inseparable and depend largely on the materials to be mixed and the degree of homogeneity to be attained. Having chosen the system the technologist will use, he can then choose the mixer.

PROPERTIES OF THE MATERIALS

Given a system of free-flowing powders to mix, the powder technologist will look closely at random mixing as the method of choice. There are many methods of gauging the flowability of a powder, but one of the more simple is an estimate of the angle of repose. This will also serve to divide materials into those which are likely to mix by an ordered or by a random process (Ref. 4). Powder flow depends on particle size (see Fig. 1), particle shape and surface forces, moisture content etc. Below about 100μm, particles become cohesive as shown by a dramatic increase in their angle of repose. At about 100μm, the angle of repose is low and largely independent of particle size. In the former region, ordered mixing will occur - even if only one of the ingredients has a particle size in this region. In the latter, non-cohesive, region, powder mixing will occur by a randomisation process.

Irregular shape, high surface forces or high moisture contents will also decrease the flowability of powders making them more prone to ordered than random mixing. Two free-flowing powders must also have very similar particle sizes if they are to be mixed by a randomisation process. If their sizes (and to

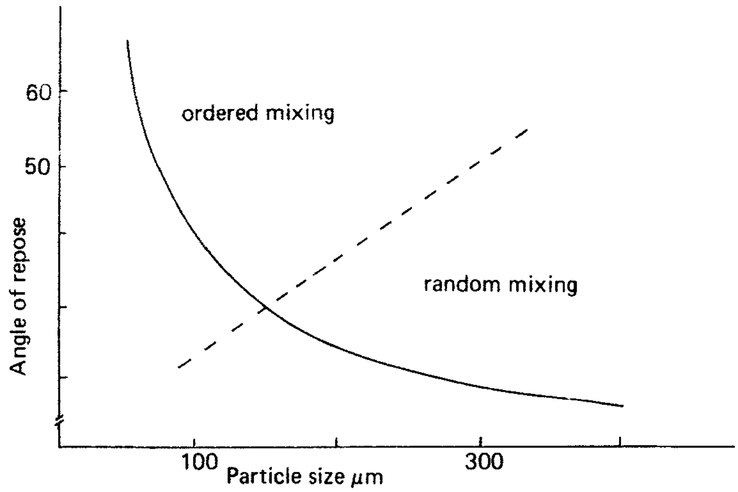

Fig. 1 Regions of mixing systems

a less extent, their densities) are dissimilar, the rate of segregation will exceed the rate of mixing. For the right system, the best powder mixers can be used to achieve almost perfect separation of the ingredients! Such systems have been used in an attempt to evaluate some mixer's performance.

The material properties can always be changed to suit the problem. Particle sizes can be reduced to either make the two powders similar for a random mixing operation or to make them (or one of them) sufficiently cohesive for ordered mixing to occur. Comminution will also reduce shape effects and increase surface forces. Drying will agglomerate the powder and make it more free flowing. The addition of moisture (or other solvent), with or without the addition of adhesive agents, will increase the cohesive nature of the powder. Thus the powder technologist has a variety of methods at his disposal to influence the system to operate as either a random mixing or an ordered mixing process.

THE DESIRED HOMOGENEITY

Before any mixing operation, the desired homogeneity must be known. For random mixing to occur to this degree of homogeneity a simple calculation based on Lacey's (Ref. 2) equation for the theoretically randomised mix is necessary,

$$\sigma_R = \sqrt{\frac{xy}{N}}$$

Where x and y are the proportions of the two ingredients and N is the number of particles in the sample - the size of which is fixed by the end-use of the mix. Assuming a normal distribution, a level of $3\sigma_R$ is reasonable, where σR is the theoretical standard deviation of the completely randomised mixture, to equate to the desired homogeneity limits. Other equations exist where the particle size is distributed (Ref. 5) or where multicomponent systems are used (Ref. 6).

These calculations yield a level of particle size required for random mixing to occur. If the powder has a maximum particle size in excess of this figure the particle size must be reduced if the desired homogeneity is to be achieved by a random mixing operation.

If the particle size yields a figure in the cohesive range of the material, then the material will either form agglomerates which will either mix as lumps in a random fashion - the desired homogeneity will not be attained, or they will be broken up and adhere to the other mix particles (ordered mixing) - to achieve the desired homogeneity. Thus the desired degree of homogeneity will also influence the choice of the system.

RANDOM OR ORDERED MIXING

Examination of the materials and of the desired degree of homogeneity will influence the choice of a random or ordered mixing process.

It is unlikely that the necessary conditions for random mixing will ever be found in practice, except in artificial systems. Furthermore segregation occurs so readily that although a reasonable mixture could be produced, emptying the mixer, further processing or transportation of the mixture, yields unsuitable levels of homogeneity.

Ordered mixtures, because particles are bound by adhering forces are far less prone to segregation (Ref. 7). They also are capable of very high levels of homogeneity (Refs. 8 & 9).

A simple test has been devised to check that ordered mixing is occuring, if the two particle sizes are widely divergent. Mix a small amount of the powders in a jar and sieve the resulting mixture at an intermediate size between the particle sizes of the two powders. If the fine material is adhering to the more coarse powder, it will not fall through the sieve but will be retained above the sieve with the more coarse material. When separation occurs, the system can be altered as outlined above and retested. When the particles are of equal size, but in the cohesive (and, therefore, subsieve) range, it can be assumed that ordered mixing can occur (although this will depend on the mixer).

CHOICE OF MIXER

1. Tumbling Mixers (gravitational)

Will produce random mixtures of free-flowing particles which are equal sized, equal dense and have similar shape and surface characteristics. If any one of these factors is not fulfilled, segregation will occur at an increasing rate as the dissimilarities increase. In general, except for artificial mixtures, this type of mixer is not recommended for randomisation. They are good separators of dissimilar free flowing materials and can be used as such.

Highly recommended for ordered mixtures containing a large proportion of large particles and a small proportion of fine cohesive particles. Dead spots should be avoided. The larger particles break down aggregates of fine particles as in a ball mill. The fine particles cohere to the large particles to form a highly homogenous system (Ref. 10). As the particle sizes are reduced methods of internal agitation to assist the break up of agglomerated particles is required.

For very fine systems, tumbling mixers are not recommended, since there is insufficient internal agitation to breakdown the agglomerated particles. Such agglomerates will tend to mix in a random fashion, rendering the comminution process a costly waste and the mixture homogeneity will be considerably less than should be attainable.

2. Stationary mixers with internal agitation

Probably the best type for random mixing of almost equal (in every sense) particulate systems, depending on both the type and degree of internal agitation. Segregation can be partially avoided by suitable choice of conditions, but will still occur on discharge etc. Can also be used for slightly cohesive systems.

For ordered mixtures, probably suitable for the slightly cohesive systems of more equal proportions.

Recommended purchase as a general purpose mixer as it is capable of most jobs irrespective of system of mixing.

3. Fluid-bed mixers

Excellent mixers for the random mixing of non-cohesive dissimilar particles - whilst fluidized. Rapid segregation occurs on cessation of air-flow, unless particles are identical.

Cohesive particles cannot be fluidized effectively. However, adhesive solutions can be added to the fluidized bed to cause agglomeration and therefore ordered mixing. Use for free-flowing systems that are required to be mixed in an ordered fashion, using the fluid-bed granulation technique. Homogeneity is somewhat limited as the particle sizes must be in the non-cohesive range initially. Alternatively, one ingredient can be added dissolved in the granulating solution. This is sprayed onto the carrier particles and forms a coated sation) of the feed. The mixing operation is sequential and serves to destroy the order introduced at the feed stage, especially for free-flowing particles. In some processes the mixing step could be eliminated, but this will depend on the constancy of the feed and the scale of scrutiny required of the mixture. The effect of the mixing operation is usually a randomisation process to overcome feed fluctuations and must be regarded as a segregating process if the materials are dissimilar.

DISCUSSION

For any given powder mixing operation there is a choice of the best system and the best mixer to achieve the end result - a desirable degree of homogeneity. The operator should be prepared not only to consider the choices available to him, but to influence the system to obtain the best result. Ordered mixing has considerable advantages over conventional random mixing processes.

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